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**DEPARTMENT OF NATIONAL DEFENCE
CANADA**



OPERATIONAL RESEARCH DIVISION

DIRECTORATE OF OPERATIONAL RESEARCH (JOINT AND LAND)

JSORT RESEARCH NOTE RN9601

**AN EXAMPLE OF HOW EXPERT SYSTEMS COULD ASSIST
OPERATIONS PLANNING**

by

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MAY 1996

OTTAWA, CANADA



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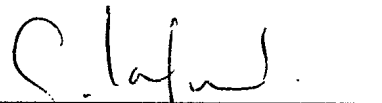
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OTTAWA, ONTARIO

MAY 1996

ABSTRACT

Expert Systems is a computer technology that automates decision trees using IF ... THEN ... ELSE rules. It has been successfully employed in areas where the diagnosis of problems involves answering a logical series of questions. The thesis of this paper is that Expert Systems could assist J3 Plans by providing the structure of an automated checklist. Using this approach, we would hope to "close the loop" from planning, to execution, to lessons learned and back to planning.

The example that is presented is from Operation Griffon. This is a new Operation Plan to provide humanitarian aid anywhere in the World on 48 hours notice. The Department of National Defence (DND) will work closely with the Department of Foreign Affairs and International Trade (DFAIT) to decide if DND should deploy the operation in a particular scenario. During the DND assessment of the situation, a checklist will be used to evaluate: the possibility of conflict in the area, the type of disaster, the geography and climate, the availability of aircraft, the readiness status of the Griffon kit, financial considerations, and other competing tasks. An automated version of this checklist has been developed as an example of how Expert Systems could be used to assist Operations Planners.

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AN EXAMPLE OF HOW EXPERT SYSTEMS COULD ASSIST OPERATIONS PLANNERS

INTRODUCTION

1. Expert Systems is a technology that attempts to automate decision trees using IF ... THEN ... ELSE rules. It has been the subject of a series of Workshops at Royal Military College (RMC) in Kingston over the past few years (see Refs 1 thru 4). The Department of National Defence (DND) together with RMC have also developed a training program for defence scientists, computer scientists and engineers which recommends the software package VP Expert (Ref 5) as a starter system. This software package was obtained by the Joint Staff Operational Research Team (JSORT) for experimental development. The purpose of this paper is to show by example how Expert Systems could assist Operations Planners.
2. The example will be based on a checklist developed by one of the authors (GF) for Operation Griffon. This Operation Plan will provide humanitarian relief anywhere in the World on short notice. The Department of National Defence (DND) will preposition approximately 20 CC130 loads of equipment and medical supplies with which to set up a field hospital in a austere location close to the disaster site. This kit will be on 48 hours notice to move out of 8 Wing Trenton.
3. The JSORT has been working on a number of aspects of the Operation Griffon planning process. In Reference 6, we highlighted some of the issues related to the airlift of the Operation Griffon kit. At Reference 7, we presented an analysis of World disasters to highlight the scenarios in which Operation Griffon might be deployed. At Reference 8, a Working Group was formed to identify the issues that remained unresolved in the Operation Griffon Plan at that time. One of the most important issues identified by the Working Group was the decision process that will be used for deciding whether or not to deploy the operation for a particular disaster scenario.

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4. The decision about whether to deploy the operation will be made in consultation with the Department of Foreign Affairs and International Trade (DFAIT). With DFAIT approval, DND will conduct an assessment of the situation and make a recommendation to the government for decision.

5. The following prototype of an automated checklist is intended to be an example of how Expert Systems could assist staff officers conducting the DND assessment for Operation Griffon.

THE MANUAL CHECKLIST

6. A manual checklist for the DND assessment was drawn up by one of the authors (GF) with the help of the J3 Plans Staff Officer in charge of writing the Operation Plan. This manual checklist is provided in Annex A. It was passed to DFAIT for their information. There are seven aspects to this assessment:

- a. Possibility of Conflict in the Area;
- b. Type of Disaster;
- c. Geography and Climate;
- d. Aircraft Availability;
- e. Kit Readiness Status;
- f. Financial Considerations; and
- g. Competing Tasks.

- 3 -

It was established that if five or more of these considerations were favourable, then the deployment was **LIKELY**. If three or more of the considerations were unfavourable, then the deployment would be **MARGINAL**. The only situation that would cause the deployment to be **UNLIKELY** would be if conflict was involved. In this case, the environment was considered "Non-Permissive" and the present Griffon team was not intended for such a scenario.

AUTOMATED CHECKLIST

7. It was not difficult to convert this manual checklist into a computer program using the Expert System programming language VP Expert (Ref 5). The User Instructions are provided in Annex B and Computer Code is provided in Annex C.

An Example Run

8. When the program is initiated the message in Figure 1 is shown on the screen. It should be emphasized that this program is only a prototype and a finalized version might provide a more elegant interface and possibly deal with more complex situations and decision making.

A PROTOTYPE OF AN AUTOMATED CHECKLIST FOR OPERATION GRIFFON

This prototype of an automated checklist will assist in the decision about whether to deploy Operation Griffon or not in a particular scenario. After answering the questions about the scenario the program will suggest that Operation Griffon deployment is either **LIKELY**, **MARGINAL** or **UNLIKELY**.

Press any key to begin the consultation.

Figure 1: The Introductory Screen for the Automated Checklist

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9. As an example, we will consider a Hurricane that has occurred on an island in Central America. We will assume that a state of peace exists and answer the questions shown in Figure 2.

What is the security environment?				
Permissive ◀	Semi-Permissive	Non-Permissive		
What type of disaster has occurred?				
Flood	Earthquake	Storm ◀	Epidemic	Famine
Other	Complex			
Where did the disaster occur?				
Americas ◀	Europe	Africa	Asia	Oceania
What is the climate in the disaster area?				
Tropical ◀	Arid	Temperate	Arctic	

Figure 2: Example of First Four Questions in the Checklist

10. The order of the questions that are asked is somewhat scenario dependent. Thus slightly different questions or a different ordering of the questions may occur depending on your answers to the previous questions. For example, if you had answered "Non-permissive" to the first question, the program would have gone directly to the recommendation that deployment was "UNLIKELY".

11. Figure 3 shows the remaining questions that need to be answered for this scenario. Notice that the first question in Figure 3 requires a numerical input. It should also be noted that the user can enter a "?" to go to the next question if the answer is unknown.

12. After answering these questions, the automated checklist is prepared to provide a recommendation. This recommendation is shown in Figure 4.

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What is the distance from the airhead to the cite?			
100			
Is land route from airhead to cite accessible?			
Yes ◀	No		
What is the geography of the disaster area?			
Coastal ◀	Plain	Hills	Mountainous
Is tactical airlift available?			
Yes ◀	No		
Is strategic airlift required for the operation?			
Yes	No ◀		
What is the GRIFFON's readiness status?			
Ready ◀	Not ready	Reconstitution first	
Are there any competing tasks?			
Yes	No ◀		

Figure 3: Remaining Questions and Answers for This Scenario

<p>THE RESULT FROM THE PROTOTYPE DECISION ANALYSIS CHECKLIST IS:</p> <p>The deployment of Operation Griffon for this scenario is LIKELY CNF 100.</p>
--

Figure 4: The Example Recommendation Made for This Scenario

13. The recommendation in this case is that deployment is "LIKELY". The "CNF 100" refers to the Confidence Factor for this recommendation. In fact, for this simple program we have utilized the default Confidence Factor of 100. However, if J3 Plans staff is interested in developing this concept further, we could introduce more sophistication to the program to

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allow variable Confidence Factors to be determined for different scenarios. As the scenario or decision process becomes more complex, the Confidence Factor would be used to provide the decision maker with more information on the final decision.

14. To give the decision maker a clearer decision outline, he can also display the actual rules that the program used to arrive its current question or at the final conclusion.

CONCLUDING MATERIAL

15. This program is a very simple demonstration of a potentially powerful technology, namely Expert Systems. This program may never be used in isolation because there is considerable resistance to giving control to a computer program for such an important decision. However, it does demonstrate the power of this technology to handle complex decision trees using qualitative information. It is hoped that individuals reading this report will be able to imagine other potential applications of Expert Systems in Operations Planning. One individual who watched a demonstration of an early prototype immediately thought of the possibility of automating checklists for Engineering Recce parties. The authors have envisioned automating the checklists linked to the Joint Operations Planning Process (JOPP). This latter area of study could facilitate the "closing of the loop" from Operations Planning, through Operations Execution, to Lessons Learned and back to Operations Planning. Although, this would be a significant research and development project and would be beyond the capabilities of our demonstration software package VP Expert, it could have an extremely high long-term payoff.

- 7 -

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5. VP Expert - Rule-Based Expert System Development Tool; Paperback Software International; 1989.
6. Taylor, I.W.; Airlift Staff Check Tools for J3 Plans; DLogA Research Note RN-9507; December 1995.
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ANNEX A
JSORT RESEARCH NOTE RN9601
DATED MAY 1996

OPLAN GRIFFON DECISION TREE

DND ASSESSMENT OF GRIFFON CAPABILITY RELATIVE TO THE SPECIFIC DISASTER

The following checklist summarizes DND assessment criteria required for a GO/NOGO decision. Each criterion is assigned one of the following three values:

- | | | |
|----|----------|---|
| a. | LIKELY | - High probability of GO; |
| b. | MARGINAL | - Situationally dependent, additional information required; and |
| c. | UNLIKELY | - Low probability of GO. |

Assumptions: Phase 1 (DFAIT receipt and analysis of emergency aid request) has been conducted and approved for continuance with next phase.

Objective: Evaluate Phase 2 (DND assessment relative to the specific event) and provide information for Phase 3 (Government analysis and decision).

1. TYPE OF HUMANITARIAN EMERGENCY

- | | | |
|-----|------------------------|------------|
| 1.1 | FLOOD | - LIKELY |
| 1.2 | EARTHQUAKE | - LIKELY |
| 1.3 | STORM (HURRICANE, ETC) | - LIKELY |
| 1.4 | EPIDEMIC | - MARGINAL |
| 1.5 | FAMINE | - MARGINAL |
| 1.6 | OTHER | - MARGINAL |
| 1.7 | COMPLEX | - MARGINAL |

2. GEOGRAPHY/CLIMATE

- | | | |
|---------|----------------------------------|--|
| 2.1 | LOCATION | |
| 2.1.1 | AMERICAS | - LIKELY |
| 2.1.2 | EUROPE | - LIKELY |
| 2.1.3 | AFRICA | - LIKELY |
| 2.1.4 | ASIA | - MARGINAL depending upon STRATEGIC AIRLIFT |
| 2.1.5 | OCEANIA | - MARGINAL depending upon STRATEGIC AIRLIFT |
| 2.2 | CLIMATE | |
| 2.2.1 | TROPICAL | - LIKELY |
| 2.2.2 | ARID | - LIKELY |
| 2.2.3 | TEMPERATE | - LIKELY |
| 2.2.4 | ARCTIC | - MARGINAL |
| 2.3 | AIRHEAD ACCESSIBILITY | |
| 2.3.1 | AIRHEAD/CAMP ROUTE DISTANCE | |
| 2.3.1.1 | DISTANCE LESS THAN 100 KM | - LIKELY |
| 2.3.1.2 | DISTANCE GREATER THAN 100 KM | - MARGINAL if ground transport too difficult |
| 2.3.2 | AIRHEAD/CAMP ROUTE ACCESSIBILITY | |
| 2.3.2.1 | ROUTE ACCESSIBLE | - LIKELY |
| 2.3.2.2 | ROUTE INACCESSIBLE | - MARGINAL if ground transport too difficult |

- 2.4 GEOGRAPHY
 - 2.4.1 COASTAL - LIKELY
 - 2.4.2 PLAIN - LIKELY
 - 2.4.3 HILLS - LIKELY
 - 2.4.4 MOUNTAINOUS - MARGINAL if terrain unsuitable for camp or ground transport.

- 3. SECURITY ENVIRONMENT
 - 3.1.1 PERMISSIVE - LIKELY
 - 3.1.2 SEMI-PERMISSIVE - MARGINAL
 - 3.1.3 NON-PERMISSIVE - UNLIKELY

- 4. AIRCRAFT AVAILABILITY
 - 4.1 TACTICAL AIRLIFT AVAILABILITY
 - 4.1.1 TACTICAL AIRLIFT AVAILABLE - LIKELY
 - 4.1.1 TACTICAL AIRLIFT NOT AVAILABLE - MARGINAL
dependent upon OTHER COMPETING TASKS
 - 4.2 STRATEGIC AIRLIFT AVAILABILITY
 - 4.2.1 STRATEGIC AIRLIFT AVAILABLE - LIKELY
 - 4.2.2 STRATEGIC AIRLIFT NOT AVAILABLE - MARGINAL if strategic
airlift required

- 5. READINESS STATUS
 - 5.1 RECONSTITUTION REQUIRED
 - 5.1.1 YES - LIKELY
 - 5.1.2 NO - MARGINAL dependent upon current level
 - 5.2 READY - LIKELY
 - 5.3 NOT READY - MARGINAL unless can become READY.

- 6. OTHER COMPETING TASKS
 - 6.1 NO OTHER COMPETING TASKS - LIKELY
 - 6.2 OTHER COMPETING TASKS EXIST
 - 6.2.1 PRIORITY OF OTHER TASKS
 - 6.2.1.1 LOW - LIKELY
 - 6.2.1.2 EQUAL - MARGINAL unless HIGHER priority given.
 - 6.2.1.3 HIGH - MARGINAL unless HIGHER priority given.

ANNEX B
JSORT RESEARCH NOTE RN9601
DATED MAY 1996

**INSTRUCTIONS FOR RUNNING THE PROTOTYPE
OPERATION GRIFFON DECISION SUPPORT TOOL**

The decision support tool written by the JSORT for Operation Griffon was written in a language called VPX. This language facilitates the development of Expert Systems which implement Rule-Based Decision Trees. Unfortunately, our version of VPX is a DOS application. However, you will find it very easy to learn.

STEP 1: Get out of Windows and into DOS. You should have the prompt C:\ or C:\WINDOWS or C:\WIN or something like that.

STEP 2: Insert the diskette in the A: drive and then type "A:\" and press <ENTER>.

STEP 3: At the prompt A:\ type "VPX" and press <ENTER>.

STEP 4: Hit any key to begin VPX session.

STEP 5: Press <ENTER> with the word CONSULT highlighted.

STEP 6: Press <ENTER> with the word GRIFFON.KBS highlighted to load the file.

STEP 7: Press <ENTER> with the word GO highlighted to run the Griffon program.

STEP 8: Hit any key to start the checklist.

STEP 9: Press <ENTER> with the word highlighted to choose an answer. Move around the menu with the Left, Right, Up and Down Arrow keys to change the highlighted word. To change your answer, highlight the word and press the <DELETE> key. To accept your answer and go to the next question press the <END> key. If you do not know the answer, you can type ? and press <ENTER> to go to the next question.

STEP 10: Answer the questions until the program provides a recommendation.

STEP 11: After reading the recommendation, press any hit to get back to the start.

STEP 12: Press <ENTER> with the word GO highlighted to run again.

If you have any comments or questions, do not hesitate to call Ivan Taylor of the JSORT at 995-2366.

ANNEX C
 JSORT RESEARCH NOTE RN9601
 DATED MAY 1996

VP EXPERT COMPUTER CODE

ACTIONS

DISPLAY "A PROTOTYPE OF AN AUTOMATED CHECKLIST FOR OPERATION GRIFFON

This is a prototype of an automated checklist will assist in the decision about whether to deploy Operation Griffon or not in a particular scenario. After answering the questions about the scenario the program will suggest that Operation Griffon deployment is either LIKELY, MARGINAL or UNLIKELY.

Press any key to begin the consultation.~"

```
CLS
TL=0
TM=0
STM=0
FIND SE
WHILETRUE ANSWER=LIKELY THEN
FIND DT
FIND L
FIND C
FIND AA1
FIND AA2
FIND AA
FIND G
FIND GC
FIND TA
FIND SAR
FIND AV
FIND READY
FIND PRIOR
FIND DECISION
END
```

CLS

DISPLAY "THE RESULT FROM THE PROTOTYPE DECISION ANALYSIS CHECKLIST IS:

The deployment of Operation Griffon for this scenario is {#Decision}.~";

RULE 1

```
IF    Sec_Env = Non-Permissive
THEN  DECISION=UNLIKELY
      ANSWER=UNLIKELY cnf 44
      SE= 3
ELSE  ANSWER=LIKELY;
```

```
RULE 1A IF Sec_Env = Permissive
THEN  SE=1
      TL=(TL+1)
```

ELSE SE=2
TM=(TM+1);

RULE 2 IF Disaster_Type = FLOOD OR
Disaster_Type = EARTHQUAKE OR
Disaster_Type = STORM
THEN DT=1
TL=(TL+1)
ELSE DT=2
TM=(TM+1);

RULE 3 IF Location = Americas OR
Location = Europe OR
Location = Africa
THEN L=1
STAT=0
SA=1
ELSE STAT=1
FIND SA;

RULE 3A IF Str_Air=Yes
THEN L=1
SA=1
ELSE L=2
STM=(STM+1)
SA=2;

RULE 4 IF Climate = Arctic
THEN STM=(STM+1)
C=2
ELSE C=1;

RULE 5 IF Airhead Proximity > 100 AND
GROUND=YES
THEN AA1=2
ELSE AA1=1;

RULE 6 IF Accessibility = No AND
GROUND=YES
THEN AA2=2
ELSE AA2=1;

RULE 6END IF AA1=2 OR
AA2=2
THEN STM=(STM+1)
AA=2
ELSE AA=1;

RULE 7 IF Geography=Mountainous AND
GROUND=YES OR
TERRAIN=NO
THEN G=2
STM=(STM+1)
ELSE G=1;


```

RULE 7END IF STM>2
THEN  TM=(TM+1)
      GC=2
ELSE  GC=1;

```

```

RULE 8  IF Tac_Air=Yes
THEN    TA=1
ELSE    TA=2;

```

```

RULE 9  IF STAT=0
THEN    SAR=0
        FIND SAL1
ELSE    SAR=1;

```

```

RULE 9A  IF S_Air=Yes AND
          STR_AIR1=NO
THEN     SAL1=2
          SA=2
ELSE     SAL1=1;

```

```

RULE 9END IF TA=2 OR
          SA=2
THEN     AV=2
          TM=(TM+1);

```

```

RULE 10  IF READINESS=NOT_READY AND
          READINESS1= NO
THEN     READY=2
          TM=(TM+1);

```

```

RULE 10A  IF READINESS=RECONSTITUTION_REQUIRED AND
           READINESS2=MUCH
THEN      READY=2
           TM=(TM+1);

```

```

RULE 11  IF COMPETE=YES AND
          PRIORITY<>LOW AND
          PRI_CHANGE=NO
THEN     PRIOR=2
          TM=(TM+1);

```

```

RULE 10  IF TM>=2
THEN     DECISION = MARGINAL
          ANSWER=UNLIKELY
ELSE     DECISION = LIKELY
          ANSWER=UNLIKELY;

```

ASK Sec_Env: "How is the security environment?";
CHOICES Sec_Env: Permissive, Semi-Permissive, Non-Permissive;

ASK Disaster_Type: "What type of disaster has occurred?";
CHOICES Disaster_Type: Flood, Earthquake, Storm, Epidemic, Famine, Other, Complex;

ASK Location: "Where did the disaster occur?";
CHOICES Location: Americas, Europe, Africa, Asia, Oceania;

ASK Climate : "How is the climate of the disaster area?";
CHOICES Climate : Tropical, Arid, Temperate, Arctic;

ASK Airhead_Proximity: "What is the distance from the airhead to the cite?";

ASK Accessibility: "Is land route from airhead to cite accessible?";
CHOICES Accessibility: Yes, No;

ASK Ground : "Is ground transport too difficult?";
CHOICES Ground: Yes, No;

ASK Geography : "How is the geography of the disaster area?";
CHOICES Geography : Coastal, Plain, Hills, Mountainous;

ASK Terrain : "Is terrain suitable for camp?";
CHOICES Terrain : Yes, No;

ASK Str_Air: "Is strategic airlift available?";
CHOICES Str_Air: Yes, No;

ASK S_Air: "Is strategic airlift required for the operation?";
CHOICES S_Air: Yes, No;

ASK Str_Air1: "Is strategic airlift available?";
CHOICES Str_Air1: Yes, No;

ASK Tac_Air: "Is tactical airlift available?";
CHOICES Tac_Air: Yes, No;

ASK Readiness : "What is the GRIFFON's readiness status?";
CHOICES Readiness : Ready, Not_ready, Reconstitution_first;

ASK Readiness1 : "Can GRIFFON become ready?";
CHOICES Readiness1 : Yes, No;

ASK Readiness2 : "How much reconstitution is required?";
CHOICES Readiness2 : Much, Acceptable_amount;

ASK Compete : "Is there any competing task?";
CHOICES Compete : Yes, No;

ASK Priority : "What is the priority of other tasks?";
CHOICES Priority : Low, Equal, High;

ASK Pri_Change : "Do you give a higher priority to the current situation?";

CHOICES Pri_Change : Yes, No;

CHOICES Decision: LIKELY, MARGINAL, UNLIKELY;

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4. AUTHORS (last name, first name, middle initial) <p style="text-align: center;">Taylor, Ivan W., Dr. Frank, G.W. and Major Gürsel, E.</p>		
5. DATE OF PUBLICATION (month Year of Publication of document) May 1996	6a. NO OF PAGES (total containing information. Include Annexes, Appendices, etc.) <p style="text-align: center; font-size: 1.2em;">17</p>	6b. NO OF REFS (total cited in document) <p style="text-align: center; font-size: 1.2em;">8</p>
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Expert Systems is a computer technology that automates decision trees using IF ... THEN ... ELSE rules. It has been successfully employed in areas where the diagnosis of problems involves answering a logical series of questions. The thesis of this paper is that Expert Systems could assist J3 Plans by providing the structure of an automated checklist. Using this approach, we would hope to "close the loop" from planning, to execution, to lessons learned and back to planning.

The example that is presented is from Operation Griffon. This is a new Operation Plan to provide humanitarian aid anywhere in the World on 48 hours notice. The Department of National Defence (DND) will work closely with the Department of Foreign Affairs and International Trade (DFAIT) to decide if DND should deploy the operation in a particular scenario. During the DND assessment of the situation, a checklist will be used to evaluate: the possibility of conflict in the area, the type of disaster, the geography and climate, the availability of aircraft, the readiness status of the Griffon kit, financial considerations, and other competing tasks. An automated version of this checklist has been developed as an example of how Expert Systems could be used to assist Operations Planners.

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